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1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100	

System and Method For Reducing Bandwidth Consumed By Looping Message Packets In Local Area Network

FIELD OF THE INVENTION

The invention relates generally to the field of digital information communications, and more particularly to systems and methods for reducing the amount of bandwidth that may be taken up by looping message packets in a local area network.

BACKGROUND OF THE INVENTION

Digital networks have been developed to facilitate the transfer of information, including data and programs, among digital computer systems and other digital devices. A variety of types of networks have been developed and implemented, including so-called "wide-area networks" (WAN's) and "local area networks" (LAN's), which transfer information using diverse information transfer methodologies. Generally, LAN's are implemented over relatively small geographical areas, such as within an individual office facility or the like, for transferring information within a particular office, company or similar type of organization. On the other hand, WAN's are generally implemented over relatively large geographical areas, and may be used to transfer information between LAN's as well as between devices that are not connected to LAN's. WAN's also include public networks, such as the Internet, which can carry information for a number of companies.

Generally, in both LANs and WANs route information is transferred among devices connected in networks in the form of message packets, employing routers, bridges, gateways and other switching devices (generally, routers) to transfer the message packets thereamong. The routers are interconnected in a mesh pattern. A LAN that is connected to a WAN typically includes a firewall to mediate communications between the LAN and the WAN. Since the routers in a LAN, as well as a WAN, are connected in a mesh pattern, errors can arise in which message packets are transferred in loops. As more and more message

1 packets are caught up in a loop, the network bandwidth devoted to such message packets increases,
2 decreasing the bandwidth available for other message packets at least in that region of the network.

3 To address this problem, message packets are typically provided with "time to live" information,
4 which allows a message packet to be discarded if it remains in the network for too long a time. Typically,
5 both LANs and WANs make use of message packet transfer protocols conforming to, for example, the
6 well-known Internet protocol ("IP"), which specifies a relatively long time to live. While this does not cause
7 a significant problem in WANs such as the Internet, it can allow message packets caught in a loop in a
8 LAN to live for a long enough period of time that they can seriously degrade network performance.

9 SUMMARY OF THE INVENTION

10 The invention provides a new and improved system and method for reducing the amount of
11 bandwidth that may be taken up by looping message packets in a local area network

12 In brief summary, the invention in one aspect provides a device for connection to a communication
13 link in a local area network. The device includes a message packet generator for generating a message
14 packet for transmission over the network. In generating the message packet, the message packet generator
15 provides a time to live field that contains an initial value that is preferably selected to be a function of the
16 maximum path length for transfer of message packets within the local area network.

17 In another aspect, the invention provides a firewall for connection between a local area network
18 and an external network. The firewall receives message packets from the external network for transmission
19 to a destination device connected to the local area network, each message packet including a time to live
20 field. The firewall, prior to transmitting the message packet over the local area network, substitutes for the
21 value in the time to live field a value that is preferably selected to be a function of the maximum path length
22 for transfer of message packets within the local area network. For message packets that the firewall
23 receives from the local area network for transmission over the external network, the firewall substitutes a

1 default initial value that is selected for use for message packets transmitted over the external network in the
2 time to live field, which typically will be significantly higher than the initial value that is used in the local area
3 network.

4 Since the initial time to live value used in the local area network is preferably selected to be a
5 function of the maximum path length for transfer of message packets within the local area network, it can
6 be much lower than the value that is typically used. This can reduce the bandwidth taken up by message
7 packets that are in a loop in the local area network, which, in turn, can allow for increased bandwidth
8 available for message packets that are being transferred through a portion of the loop but which are not
9 themselves looping through the entire loop.

BRIEF DESCRIPTION OF THE DRAWINGS

10 This invention is pointed out with particularity in the appended claims. The above and further
11 advantages of this invention may be better understood by referring to the following description taken in
12 conjunction with the accompanying drawings, in which:

13
14 FIG. 1 is a functional block diagram of a network domain constructed in accordance with the
15 invention;

16 FIG. 2 depicts the structure of an illustrative message packet used in connection with the network
17 domain depicted in FIG. 1; and

18 FIG. 3 is a flow chart depicting operations performed by a firewall used in the network domain
19 depicted in FIG. 1 in connection with the invention.

DETAILED DESCRIPTION OF AN ILLUSTRATIVE EMBODIMENT

FIG. 1 is a functional block diagram of a network domain 10 constructed in accordance with the invention. With reference to FIG. 1, network domain 10 includes a plurality of sub-domains 11(1) through 11(6) (generally identified by reference numeral 11(n)) and at least one firewall 12 interconnected by a plurality of communication links generally identified by reference numeral 13(p). Generally, the firewall 12 operates to regulate communications between the network domain 12, which may be a local area network maintained by a private organization, and devices (not shown) external to the network domain 10 that may wish to communicate with devices in the network domain 10 over, for example, a public network such as the Internet, the public switched telephony network (PSTN) and the like, as will be described below.

As noted above, network domain 10 includes a plurality of sub-domains 11(n). Each sub-domain 11(n), in turn, comprises one or more devices generally identified by reference numeral 14(d) and at least one router 16(n) interconnected by a sub-domain communication link 15(n). Generally, the devices 14(d) transfer information in the form of message packets over the sub-domain communication link 15. For message packets that are to be transferred from a device 14(d) in one sub-domain 11(n) to a device 14(d') in another sub-domain 11(n') (n' \neq n), those message packets will be received by the router 16(n) of sub-domain 11(n) and transferred to a router 16(n') that is associated with another sub-domain 11(n₁). The sub-domain 11(n₁) may or may not be the sub-domain 11(n') that contains the destination device 14(d'). If the sub-domain 11(n₁) is the sub-domain 11(n') that contains the destination device 14(d'), the router 16(n') that receives the message packet will transmit the message packet over the communication link 15(n') associated with that sub-domain 11(n'), thereby to facilitate reception thereof by the destination device 14(n').

On the other hand, if the sub-domain 11(n₁) is not the sub-domain 11(n') that contains the destination device 14(n'), the router 16(n₁) of that sub-domain 11(n₁) that receives the message packet, will forward the message packet to a router 16(n₂) of another sub-domain 11(n₂). These operations will

1 be repeated by routers $16(n_1)$, $16(n_2)$ of successive sub-domains $11(n_1)$, $11(n_2)$... until the message
2 packet is received by the router $16(n')$ of the sub-domain $11(n')$ that contains the destination device $14(d')$.
3 When the router $16(n')$ receives the message packet, it will transmit the message packet over the
4 communication link $15(n')$ to facilitate reception by the destination device $14(n')$. The successive routers
5 $16(n_1)$, $16(n_2)$ define a path from the sub-domain $11(n)$ that contains the device $14(d)$ that is the source
6 of the message packet, and the sub-domain $11(n')$ that contains the device $14(d)$ that is the destination.

7 As yet another possibility, a device $14(d)$ may wish to send a message packet to an external device
8 (not shown), that is, a device that is not connected in the network domain 10, over the Internet, PSTN, or
9 other external network. In that case, the message packet will be transferred by the router $16(n)$ of the sub-
10 domain $11(n)$ that contains the to the firewall 12, either directly or through one or more other routers
11 $16(n_1)$, $16(n_2)$ in a manner similar to that described above. When the firewall 12 receives the message
12 packet, it can determine whether the communication between the device $14(d)$ and the external device is
13 authorized, and, if so, forward the message packet over the external network connection 17. Similarly, if
14 an external device wishes to transmit a message packet to a device $14(d)$ connected in the network domain
15 10, the firewall 12 will receive the message packet from the external network connection 17. After the
16 firewall 12 receives the message packet, it can determine whether the communication between the external
17 device and the device $14(d)$ is authorized and, if so, forward the message packet to the router $16(n)$ of the
18 sub-domain $11(n)$ which the device $14(d)$ is connected, either directly or indirectly through one or more
19 other routers $16(n_1)$, $16(n_2)$ along a path from the firewall 12 to the router $16(n)$. After the router $16(n)$
20 has received the message packet, it can transmit the message packet over the sub-domain's communication
21 link $15(n)$ to facilitate reception by the device $14(d)$. Communications between a device $14(d)$ and an
22 external device may be over a "secure tunnel," in which at least some of the information in the message
23 packets as transmitted over the external network connection 17 is in encrypted form, or alternatively the
24 information may be in plaintext; if the communications is over a secure tunnel, the firewall 12 will encrypt
25 information in the message packet as generated by the device $14(d)$ before transmitting the message packet

1 over the external network connection 17, and decrypt the encrypted information in the message packet
2 received over the external network connection 17 before forwarding it to the device 14(d).

3 The invention provides an arrangement that addresses a problem that can arise in connection with
4 transfer of message packets that are transferred throughout the network domain, primarily by the routers
5 16(n). In particular, there can arise situations in which loops develop so that, instead of a message packet
6 being transferred by the routers along a path from the router 16(n), through intermediate routers 16(n₁),
7 16(n₂)... to the router 16(n') of the sub-domain 11(n') that contains the destination device 14(d'), at some
8 point along the path the message packet is diverted in such a way that it returns to a router 16(n_x) along
9 the path previous to the router 16(n_y) (n_x < n_y) at which it was diverted. In that case, the message will
10 continue being transferred in the loop through routers 16(n_x), 16(n_{x+1}),..., 16(n_y),..., 16(n_x),..., 16(n_y)....
11 This can occur if, for example, a communication link is connected incorrectly, a router is incorrectly
12 programmed, or the like. In addition, it can occur in connection with a number of message packets. As
13 more and more message packets get caught in the loop, the bandwidth through the routers associated with
14 the loop taken up by those message packets increases, which can significantly degrade network
15 performance.

16 To address this problem, typically each message packet is provided with a so-called "time to live"
17 field, which is provided with a selected value when it is transmitted, and is decremented by each router that
18 receives it. If a router decrements the value in the time to live field to zero, it will discard the message
19 packet. While this does not eliminate the possibility of loops developing, it can attempt to limit the injury
20 by ensuring that message packets will be discarded after they have gone around at least a portion of a loop
21 a maximum number of times. Typically, message packets transmitted over wide area networks such as the
22 Internet, which also have routers that forward message packets in a manner similar to that described above
23 in connection with network domain 10, also include time to live fields to address the possibility of loops
24 developing, and for such message packets the value in the time to live field is initialized to a relatively high
25 number, typically thirty-two, to accommodate the possibility that it will not be decremented sufficiently that

1 it will be discarded along the path from the source to the destination. Typically, that same initial value is
2 also used as initial values in time to live fields of message packets that are to be transferred through LANs
3 such as network domain 10. However, that value is generally much higher than would be necessary in a
4 LAN such as network domain 10. In addition, it will be appreciated that, the higher the initial value, the
5 longer a message packet that was in a loop would remain in the loop.

6 Accordingly, in accordance with the invention, devices 14(d), when they generate message
7 packets, initialize the time to live fields to a relatively small value. The initial value is preferably selected to
8 be high enough to ensure that the value is not decremented to zero over a relatively long path to the
9 destination device within the network domain 10, and in one embodiment is selected to be on the order of
10 five. Since the initial time to live value is lower than the initial value that is normally used, if the message
11 packet gets caught in a loop, it will be discarded earlier than if the initial time to live value were the initial
12 value that is normally used. Thus, if a loop develops, message packets get caught in the loop will be
13 discarded earlier than normally, which can reduce the amount of bandwidth that is taken up by such
14 messages.

15 A device 14(d) will also use this reduced initial time to live value in connection with message
16 packets that are to be transmitted to external devices. In that case, when the firewall 12 proceeds to
17 forward the message packet over the external network connection 17, it will increase the value in the time
18 to live field to correspond to the initial value that is used in message packets transmitted over the Internet,
19 that is, thirty-two, as described above. Similarly, when the firewall 12 receives a message packet from the
20 external network connection 17, if it determines that the message packet is to be forwarded to a device
21 14(d), it will substitute the initial time to live value that is selected for use in the network domain 10 in the
22 time to live field. This substitution will generally result in a reduction in the time to live value from that in the
23 message packet as received over the external network connection 17, so that, if a loop develops in the
24 network domain 10, message packets get caught in the loop will be discarded earlier than normally, which
25 can reduce the amount of bandwidth that is taken up by such messages in the network domain 10.

1 Before proceeding further, it would be helpful to describe the structure of a message packet used
2 in connection with one embodiment of the invention. FIG. 2 depicts an illustrative message packet 20
3 including a header portion 21 and a payload data portion 22. Generally, the message packet 20 that will
4 be described in connection with FIG. 2 will conform to the format defined for the Internet protocol, but it
5 will be appreciated that any other convenient format may be used. In a message packet 20 that conforms
6 to the format defined for the Internet protocol, the header portion 21 contains information that is used by
7 the routers 16(n) and firewall 12 in connection with transmission of message packets throughout the
8 network domain 10. In addition, for message packets that a router 16(n) transmits onto its sub-domain's
9 communication link 15(n), the header portion 21 contains information that each device 14(d) uses to
10 determine whether it is to receive the respective message packet. Similarly, for message packets that the
11 firewall 12 transmits over or receives from the external network connection 17, the header portion 21
12 contains information that is used in connection with transfer of message packets through the external
13 network. The payload data portion 22 of message packet 20 contains the information that the source
14 device is to transfer to the destination device. As noted above, if message packets are to be transferred
15 over the external network over a secure tunnel, some portion of the message packets may be encrypted,
16 and it should be noted that the payload data portion 22 is the portion that is to be encrypted; in that case,
17 the information in the header portion 21 will not be encrypted since routers, switches and the like which
18 forward the message packets in the external network will need to have access to the information to route
19 the message packets to the respective destinations.

20 The header portion 21 includes a plurality of fields, including one or more fields, generally referred
21 to by reference numeral 23, which contain protocol information, a source address field 24, a destination
22 address field 25, a time to live field 26, one or more fields, generally referred to by reference numeral 27,
23 which contain miscellaneous information, and a checksum field 28. The protocol information in field(s) 23
24 may include such information as a protocol version identifier, a quality of service identifier, and a length
25 field. The quality of service identifier can identify a priority for the message packet. The length field
26 identifies the total length of the message packet. If the message packet 20 is one of a plurality of message

1 packets that together are fragments of a larger message packet, the protocol information may also include
2 a fragment offset value identifying the offset of the message packet 20 into the larger message packet; this
3 will allow the destination device to reassemble the larger message packet from the fragments. Other types
4 of protocol information will be apparent to those skilled in the art.

5 The source and destination address fields 24 and 25 identify the source device, the device that
6 generated the message packet 20, and the destination device, the device that is to receive the message
7 packet 20, respectively.

8 The time to live field 26 receives the time to live value as described above. As noted above, the
9 source device 14(d) in network domain 10 will provide an initial time to live value, and each router 16(n)
10 that receives the message packet 20 will decrement the value in the time to live field 26. Since a router
11 16(n) will discard the message packet 20 if the value in the time to live field decrements to zero, the initial
12 value provided by the source device 14(d) will preferably selected to be high enough to ensure that the
13 value is not decremented to zero over a relatively long path to the destination device within the network
14 domain 10.

15 The miscellaneous information field(s) 27 can identify various options for the message packet. A
16 number of options are defined for the Internet protocol. A security option may be selected if information
17 in the message packet is deemed sensitive, which may affect the path over which the message packet is
18 routed particularly through the external network. A source routing option may be selected whereby the
19 source device, or a router along the path to the destination device, specifies the path therefrom to the
20 destination device; in that case, the path is included in the miscellaneous information field(s) 27. In addition,
21 typically the length of the header portion 21 is required to be on octet boundaries, with each octet
22 comprising a predetermined number of bits, the miscellaneous information field(s) may include padding to
23 ensure that the header portion 21 ends on an octet boundary. The checksum field 28 includes a value
24 corresponding to the checksum of the values in the other fields 23 through 27. The checksum value can
25 be used to verify that the information in the fields 23 through 27 was correctly received. If the checksum

1 indicates that the information in fields 23 through 27 was not correctly received, the error may result in the
2 message packet being routed to a device that is not the intended destination, in which case the message
3 packet can be discarded.

4 With this background, and as noted above, the firewall 12, when it receives a message packet from
5 a router 16(n) inside the network domain 10, will substitute the normal time to live value in the time to live
6 field 26 before it transmits the message packet over the external network connection 17. This will generally
7 provide that the message packet will not be discarded before it reaches the destination device unless the
8 message packet loops. Contrariwise, the firewall 12, when it receives a message packet from the external
9 network connection 17, substitutes the initial time to live value selected for the network domain 10 in the
10 time to live field 26 before it transmits the message packet into the network domain 10, which, as noted
11 above, can serve to reduce the bandwidth taken up by message packets in a loop if a loop develops in the
12 network domain 10. Operations performed by the firewall 12 in this connection are described in the flow
13 chart depicted in FIG. 3. Since the operations will be readily apparent to those skilled in the art from the
14 above description, they will not be described further herein.

15 The invention provides a number of advantages. In particular, the invention provides an
16 arrangement that facilitates use of a time to live values within the network domain 10 that can reduce the
17 bandwidth taken up by message packets that are in a loop in the network domain 10, which can allow for
18 increased bandwidth available for message packets that are being transferred through a portion of the loop
19 but which are not themselves looping through the entire loop.

20 It will be appreciated that a number of modifications may be made to the arrangement described
21 above in connection with FIGS. 1 through 3. For example, the devices 14(d) can be any kind of devices
22 which may be connected in a network domain 10, including any type of computers (illustratively, personal
23 computers, workstations, mini- and mainframes), as well as devices, such as mass storage systems,
24 network printers, and other devices that can store, process and otherwise make use of digital information.
25 Although the network domain 10 has been described as making use of routers to transfer message packets

1 between and among sub-domains 11(n), it will be appreciated that any type of device that can switch
2 message packets among a plurality of inputs and outputs may be used, including, for example, switching
3 nodes, bridges, gateways, and the like. Furthermore, although the network domain has been described
4 as making use of message packets that conform to the format specified in the Internet protocol, it will be
5 appreciated that message packets of any format can be used, provided they contain a field that performs
6 a function similar to that provided by the time to live field. For example, a message packet that conforms
7 to the format defined by the CLNP (ConnectionLess Network Protocol) protocol includes a "lifetime" field
8 that performs a function similar to that provided by the time to live field 26. In addition, message packets
9 can be transferred over communication links 13(p) and 15(n) using any convenient transfer protocol or
10 protocols. Illustratively, message packets may be transferred over the intra-sub-domain communication
11 link 15(n) using, for example, the well-known Ethernet protocol, a token ring protocol, or any other
12 convenient protocol.

13 It will be appreciated that a system in accordance with the invention can be constructed in whole
14 or in part from special purpose hardware or a general purpose computer system, or any combination
15 thereof, any portion of which may be controlled by a suitable program. Any program may in whole or in
16 part comprise part of or be stored on the system in a conventional manner, or it may in whole or in part be
17 provided in to the system over a network or other mechanism for transferring information in a conventional
18 manner. In addition, it will be appreciated that the system may be operated and/or otherwise controlled
19 by means of information provided by an operator using operator input elements (not shown) which may
20 be connected directly to the system or which may transfer the information to the system over a network
21 or other mechanism for transferring information in a conventional manner.

22 The foregoing description has been limited to a specific embodiment of this invention. It will be
23 apparent, however, that various variations and modifications may be made to the invention, with the
24 attainment of some or all of the advantages of the invention. It is the object of the appended claims to cover
25 these and such other variations and modifications as come within the true spirit and scope of the invention.

1 What is claimed as new and desired to be secured by Letters Patent of the United States is:

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